DISCOVERY

Assessment of n-decane concentration in the diffusion of crude oil in different soil environment of Aluu in Niger Delta

Wecheonwu BC, Onyekwulu CS

To Cite:
Wecheonwu BC, Onyekwulu CS. Assessment of n-decane concentration in the diffusion of crude oil in different soil environment of Aluu in Niger Delta. *Discovery* 2023; 59: e66d1247

Author Affiliation:
Lecturer, Department of Chemical Engineering, Madonna University, Nigeria

Peer-Review History
Received: 01 May 2023
Reviewed & Revised: 04/May/2023 to 14/May/2023
Accepted: 18 May 2023
Published: June 2023

Peer-Review Model
External peer-review was done through double-blind method.

Discovery
pISSN 2278–5469; eISSN 2278–5450

ABSTRACT

The assessment of n-decane concentration in the diffusion of crude oil in different soil environment was investigated by the help of experiment. Three cylindrical reactors 125cm high and 13.8cm in diameter were designed and transferred three different soils into the reactors clay soil, loamy soil and sandy soil respectively. In every two weeks samples were collected from the first point of the three reactors to test with Gas Chromatography (GC) to determine the concentration of n-decane (C_{10}) hydrocarbons present. The process lasted for two months two weeks. It was observed that there was decrease in n-decane (C_{10}) hydrocarbon degradation was observed with increase in time. The decrease may be attributed to the order of magnitude of the individual hydrocarbon degradation and diffusion in the various soil samples revealed that the decrease in sandy soil is greater than that of clay soil and loamy soil, while that of clay soil is greater than that of loamy soil, which can be presented in simpler form as (SS > CS > LS) and the characteristics of the behavior of the C_{10} individual hydrocarbon degradation in this case can be attributed to the physicochemical properties of the soil as well as the environmental factors.

Keywords: Assessment, diffusion, crude, Aluu, Niger Delta

1. INTRODUCTION

Decane is an alkane hydrocarbon with the chemical formula $C_{10}H_{22}$. Although 75 structural isomers are possible for decane, the term usually refers to the normal-decane (''n-decane''), with the formula CH_3 $(CH_2)_5CH_3$ (75 isomers of Decane, 2016). The initiated experimental impact of crude oil physical features on their diffusion rate in a soil environment was discovered that, once crude oil spilled into the soil medium, the impacts that crude oil kinematic viscosity (ratio of dynamic viscosity to density) exercised on the longitudinal and vertical diffusion rate of crude oil, had been profound (Petroleum Cheemistry Encyclopedia, 2016; HSDB, 2022; Griesaum et al., 2000). Oghenejobah and Puyate, (2010) and Wang et al., (2013) used fluorescent correlation of water-soluble interfaces was made for

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diffusion of smaller fluorescent molecules at the n- decane/water interface. At room temperature (~22oC) the viscosities of n-decane and water become very close to each other. Therefore, a naïve prediction suggests that the diffusion coefficient of a small molecule incorporated at the n-decane/water interface would be the same as that in bulk water. The n-decane according to Cummings and Ubbelohde, (1953) and Altshuller and Cohen, 1960 were carried out above 310oK. The measured diffusivities over 313-422oK agree well with the estimated values, though, it appears that the difference between larger and higher temperature if extrapolated to 298oK, the two measurements show good agreement. The preferred value, (44±2) Torrcm2s-1, is the average of those extrapolated to 298oK from those measured at 364oK by Wang et al., (2013) and at 313oK by Cummings and Ubbelohde, (1953).

The interfacial diffusion behavior of the smallest tracer which the atomic-level insight was entered into rhodamine 6G (R6G) through atomic molecular dynamics simulation is in agreement with Griesaum et al., (2000) we find increased mobility of the tracer at n-decane/water interface in comparison to it value in bulk water (Popov et al., 2015).

2. EXPERIMENTAL PROCEDURE

Experimental Set-up for the Diffusion of Crude Oil in Soil Environment

A reactor 125cm high and 13.8cm in diameter was set up. The reactor was divided into two parts- one parts for the collection of soil samples and the other part for the collection of crude- oil and water. The cylindrical reactor was calibrated in centimeters (cm) and numbered from 0 to 125cm. 1cm to 10cm was the volume of water and crude-oil and from 10cm to 125cm contains soil samples. Openings for collection of samples were constructed leaving 5cm from 10cm, starting from 15cm to 17cm. The openings were constructed in squares of 2cm by 2cm for the collection of samples for testing. The distance between the one opening and the other opening was 19cm. The openings were positioned as follow: The first 15cm-17cm, second 36cm–38cm, third 57cm-59cm, fourth 81cm-83cm, fifth 99cm–101cm and finally, the sixth 123cm-125cm.

Since the reactors were cylindrical in shape, the volume of soil samples and crude-oil + water can be calculated using the volume of a cylinder. The bases of the cylindrical reactors were covered with inverted plastic buckets of equal diameters and heights filled with soil for reinforcement so that the buckets cannot be compressed when the reactors will be loaded with soil samples. This is to ensure that the weight of the soil samples in the reactors will be at equilibrium with the base. Clips of 6inches in diameter were used to fasten the reactors to the clamps of retort stands, holding the base with cubic blocks of 16cm by 16cm to prevent the reactors from falling down. The volume of crude-oil and water in the cylindrical reactor can be calculated using the formula:

$$V_{cw} = \pi\, r^2 h_{cw} \text{ and } V_s = \pi\, r^2 h_s \quad (1)$$

Where;

$V_{cw} = volume\ of\ crude - oil + water\ in\ cylindrical\ reactor$

$r = radius\ of\ cylinderical\ Reactor$

$h_{cw} = height\ of crude - oil + water\ in\ cylindrical\ reactor$

$V_s = volume\ of\ soil\ sample\ in\ cylindrical\ reactor$

$h_s = height\ of\ soil\ sample\ in\ cylindrical\ reactor$

$\pi = 3.142$

$$V_s = \pi\, r^2 h_s \quad (2)$$

$h_s = 125cm - 10cm = 115cm$

$D = diameter\ of\ reactor = 13.8cm$

$r = radius\ of\ reactor = \frac{D}{2} = \frac{13.8cm}{2} = 6.9cm$

$$V_s = 3.142\ x\ (6.9cm)^2\ x\ 115cm = 17202.9213cm^3$$

$$V_s = \approx 17203cm^3$$

$$V_{cw} = 3.142\ x\ (6.9cm)^2\ x\ 10cm = 1495.9062cm^3$$

$$V_{cw} = 1496cm^3$$

The ratio of crude to water in the reactor is the same as in the cylindrical reactor. If the volume of the crude and water is 1496cm^3 so, the volume of crude oil +volume of water

$$= \frac{1496cm^3}{2} = 748cm^3$$

The ratio of soil sample: water: Crude–oil

$$\frac{17203cm^3}{748cm^3} : \frac{748cm^3}{748cm^3} : \frac{748cm^3}{748cm^3}$$

$$22.998 : 1 : 1$$

$$23 : 1 : 1$$

The soil samples made up of loamy sand, clay sand and sandy sand were loaded into the reactors with the help of a container through the upper opening of the reactors. As the loading was taking place at every 10cm, compartment took place until it got to the height of 10cm from 125cm. Then, water was measured using 500cm^3 measuring cylinder. First 500cm^3 and 248cm^3 making it up to 748cm^3 and the same volume of crude-oil was also measured and mixed with water, before transferred into the reactors. In the course of mixing the crude–oil with water the crude floated on top of the water meaning that water is denser than crude – oil. Also, water is an inorganic solvent and crude–oil is an organic compound, which cannot dissolve in water. Between 45minutes to one hour it was discovered that the liquid component of the reactors had diffused into the loamy and sandy soils while, that for the clay the liquid component was still stagnant in the reactor. The water in the reactor was intended to act as a driving force. The diffusive and advective flow was also contributing to the diffusion of the liquid component in y-direction. In x-direction it was advective flow due to dispersion and concentration gradient. The samples were collected at the interval of fourteen (14) days (2weeks) to test for the required parameters for five times of collection.

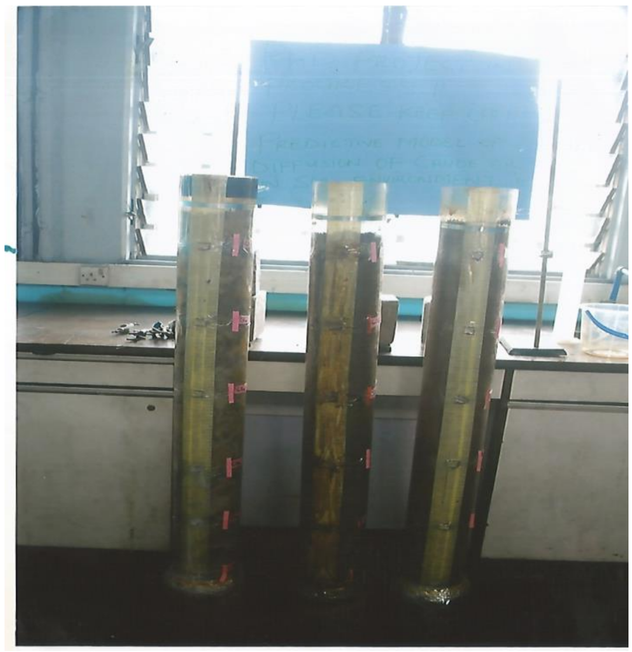

Figure 1 Experimental Set-up for Diffusion of Crude oil in Soil Enviornment

3. RESULT AND DISCUSSION

Figure 2 illustrates the gas chromatography (GC) result of the crude oil sample used for this research work. The following individual hydrocarbons were identified such as n-octane (C8), n-Nonane (C9), Decane (C10), n-Undecane (C11), n-dodecane (C12), n-tridecane (C13), n-tetradecane (C14), n-pentadecane (15), n-hexadecane (C16), Priscine (Pr), n-heptadecane (17), n-octadecane (18), phypane (ph), n-nonadecane (C19), n-icosane (C20), n-henicosane (C21), n-docosane (C22), n-tricosane (C23), n-tetracosane (24), n-pentacosane (C25), n-hexacosane (C26), n-heptacosane (C27), n-octacosane (C28), n-nonacosane (C29), n-triacontane (C30), n-hentriacontane (31), n-dotriacontane (C32), ntritriacontane (C33), n-tetratriacontane (C34) and n-pentatriacontane (C35) (Figure 2).

The magnitude of the concentration of total hydrocarbons were in the decreasing order as C12> C14> C27> C18> C24> C15> C10>C13> C20>C29>ph>C26> C11> C25> C34> C8> C17> C23> C33> C21> C31> C35> C32> C9> C19> C28> C16> C30>pr> C22. This characterized the individual components of hydrocarbon present in the raw crude oil sampled revealed the order of magnitude of their concentration (Figure 2).

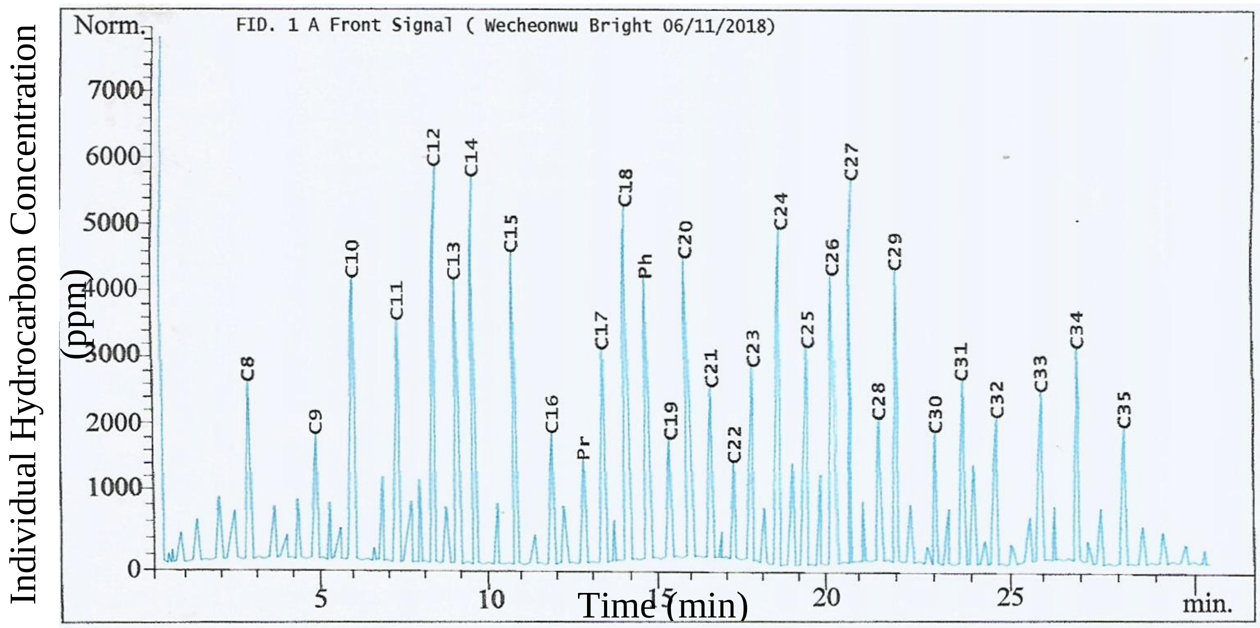

Figure 2 GC Result of Individual Hydrocarbon Identification from crude oil

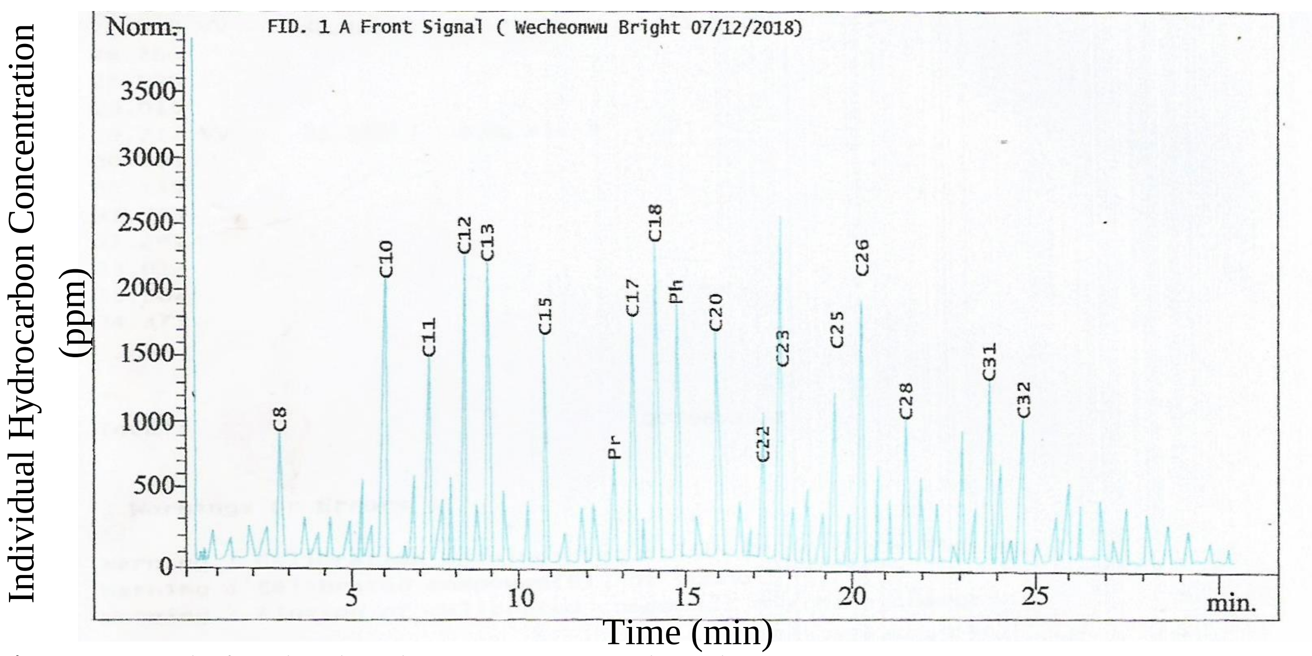

Figure 3 GC Result of Total Hydrocarbon Concentration in Clay Soil at Point 1 versus Time

Figure 3 demonstrates the gas chromatography (GC) result of the degradation of crude oil in clay soil (CS). The following individual hydrocarbons were identified such as n-octane (C8), n-decane (C10), n-undecane (C11), n-dodecane (C12), n-tridecane (C13), n-pentadecane (C15), priscine (pr), n-heptadecane (C17), n-octadecane (C18), phypane (ph), n-icosane (C20) n-docosane (C22), n-tricosane (C23), n-pentacosane (C25), n-hexacosane (C26), n-octacosane (C28), n-hentriacontane (C31) and n-dotriacontane (C32) (Figure 3).

The magnitude of the concentration of the total hydrocarbons diffusion in collection point one (1) of clay soil were in the decreasing order as stated below; C18> C25> C12> C13> C10> ph> C28> C17> C15> C20> C11> C31> C23> C8> C32>pr. This characterized the individual components of degraded hydrocarbons in the clay soil (CS) sample in the reactors point one revealed the order of magnitude of their concentration (Figure 3). The disappearance of some individual hydrocarbons present in the crude sample may be as a result of activities of the microorganisms present in the process.

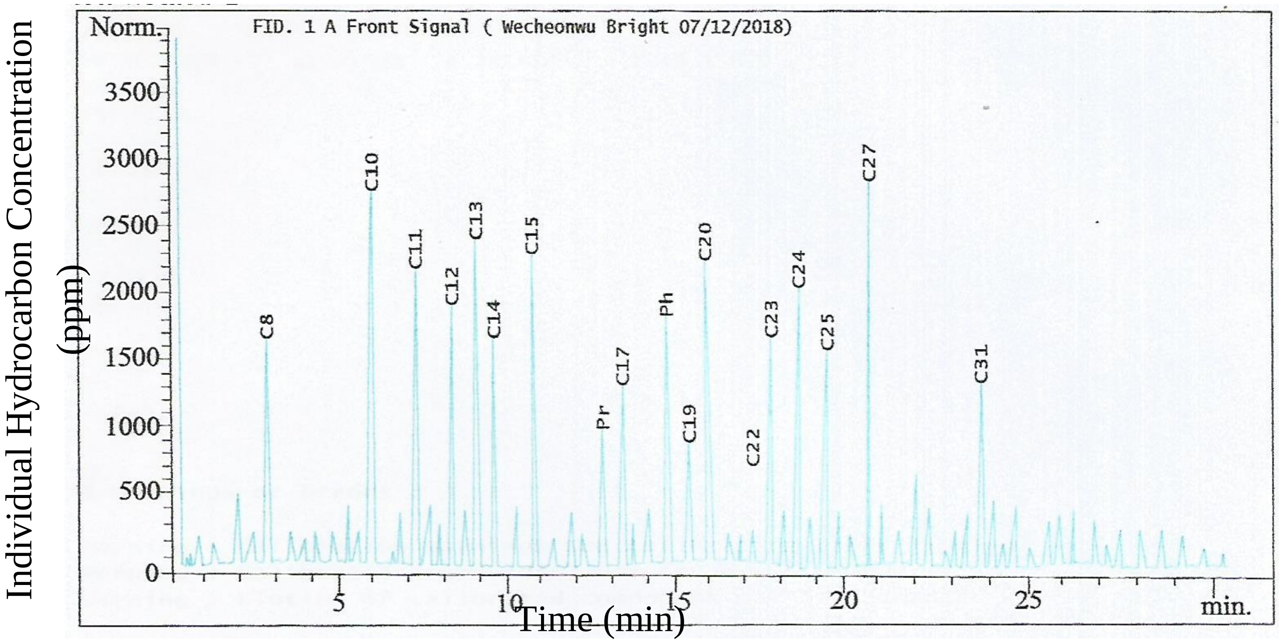

Figure 4 GC Result of Total Hydrocarbon Concentration in Sandy Soil at Point 1 versus Time

Figure 4 shows the gas chromatography (GC) results of the degradation of crude oil in sandy soil point one. The individual hydrocarbons discovered were octane (C8), Decane (C10), undecane (C11), dodecane (C12), tridecane (C13), tetradecane (C14), pentadecane (C15), priscine (pr), heptadecane (C17), phypane (ph), icosane (C20), docosane (C22), heptacosane (C27) and hentria contane (C31).

The total hydrocarbons present are in the order decreasing magnitude as in Figure 4, as C10> C27> C13> C15> C11>20> C24> C12>ph> C8> C14> C25> C25> C23> C17> C31>pr. This characterized the individual components of degraded hydrocarbons in the sandy soil (SS) sample in the reactor point one revealed the order of magnitude of their concentration (Figure 4). The disappearance of some individual hydrocarbons present in the crude oil sample may be as result of action of the microorganisms present during the degradation process.

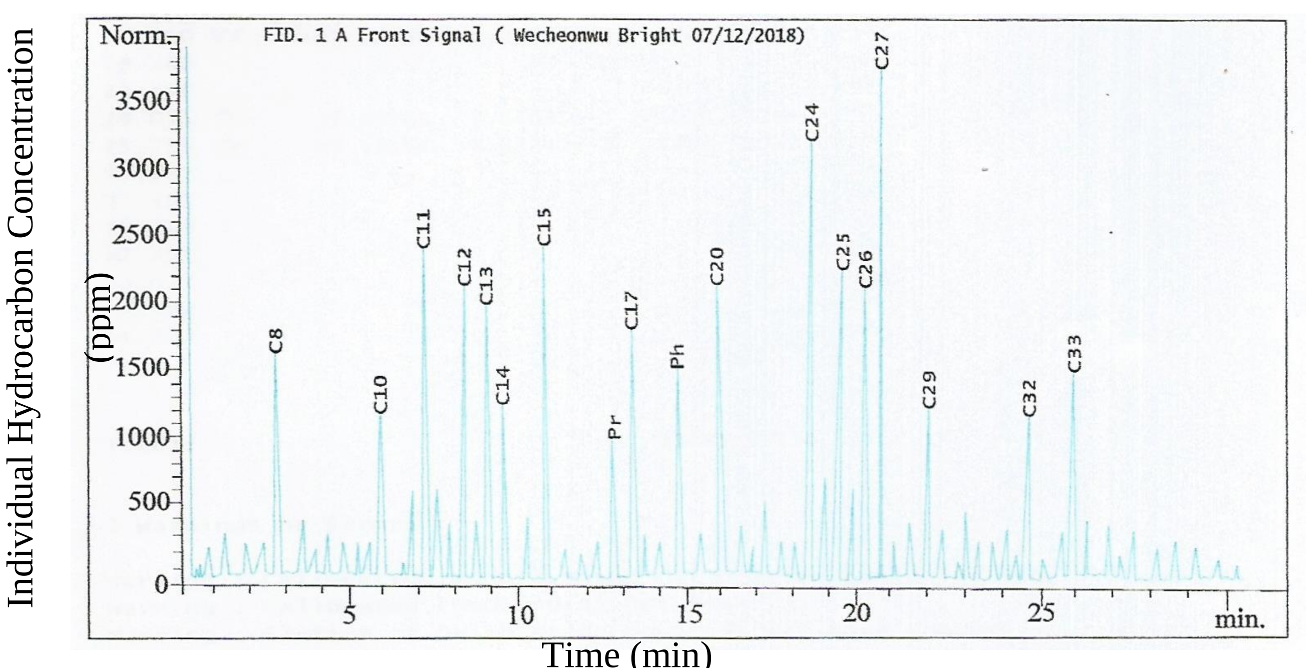

Figure 5 GC Result of Total Hydrocarbon Concentration in Loamy Soil at Point 1 versus Time

Figure 5 Demonstrates the gas chromatography (GC) result of the degradation of crude oil in loamy soil point one. The individual hydrocarbons identified were n-octane (C8), n-decane (C10), n-undecane (C11), n-dodecane (C12), n-tridecane (C13), n-tetradecane (C14), n-pentadecane (C15), priscine (pr), n-heptadecane (C17), phypane (ph), n-icosane(C20), n-tetracosane (C24), n-pentacosane (C25), n-hexacosane (C26), n-heptacosane (C27), n-nonacosane (C29), n-dotriacontane (32) and n-tritriacontane (C33).

The total hydrocarbon present were in the order of decreasing magnitude as in Figure 5 as C27> C24> C11> C15> C25> C12> C13> C26> C20> C17> C8>ph> C29> C14> C10> C33> C32>pr. This characterized the individual hydrocarbons components of degraded hydrocarbons in the loamy soil (LS) sample in the packed reactor point one revealed the order of magnitude of their concentration (Figure 5). The missing of some individual hydrocarbon present in crude oil sample could be attributed to the breaking down of hydrocarbon (crude oil) into individual hydrocarbons by the microorganisms present in the process.

Table 1 Concentration of Diffused $\boldsymbol{C_{s(\tau)}} = \boldsymbol{C_o} - \boldsymbol{C_o e^{-\frac{t}{\tau}}}$ at Constant Coefficient Concentration of Diffused Hydrocarbon (g/mol.)

Time (day)	Hydrocarbon Component	Clay Soil	Loamy Soil	Sandy Soil	Coefficients of τ (day^{-1})
0	C10	0.004231	0.00423	0.004231	0.01
14		0.002163	0.001229	0.002864	0.01
28		0.001427	0.000718	0.001928	0.01
42		0.001035	0.000461	0.001285	0.01
56		0.000751	0.000318	0.001035	0.01
70		0.000483	0.000126	0.000816	0.01

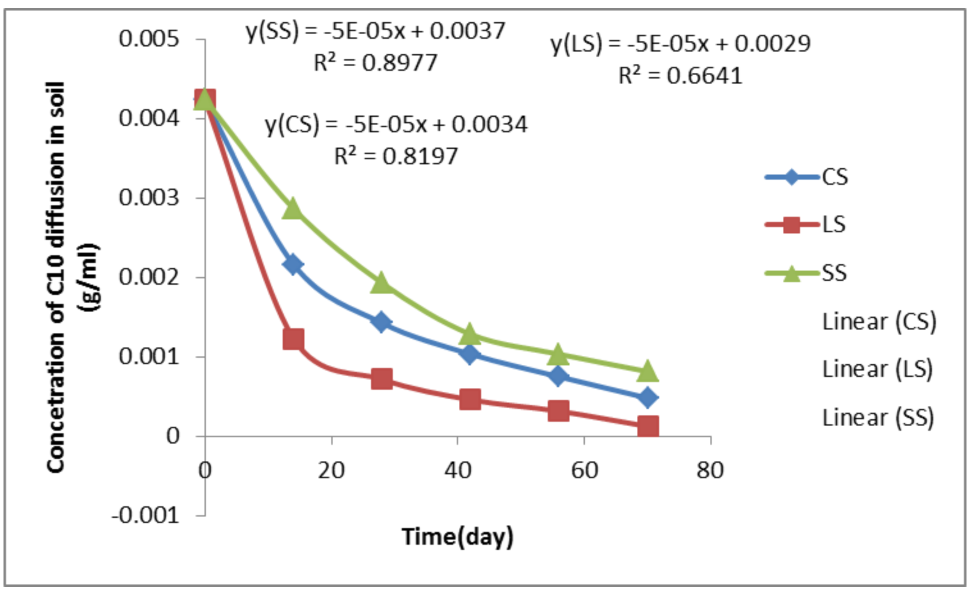

Figure 6 Graph of Concentration of C_{10} Degradation versus Time for Various Environment of Clay, Loamy and Sandy Soil

Figure 6 demonstrates the relationship between the concentration of C_{10} individual hydrocarbon degradation and exposure time for various soil environment of clay, loamy and sandy soil upon the influence of diffusion from one level to another in the packed column system. The variation in the concentration of C_{10} individual hydrocarbon degradation can be attributed to the exposure time as well as the rate of diffusion of the C_{10} hydrocarbon in each soil environment. The equation of the curve is obtained as $Y_{ss} = -5E - 05X + 0.0037$ with the square value of $R_{ss}^2 = 0.8977$, $Y_{cs} = -5E - 05X + 0.0034$ with the square root value of $R_{cs}^2 = 0.8197$ and for loamy soil we have $Y_{ls} = -5E - 05X + 0.0029$ with the square root value of $R_{ls}^2 = 0.6641$.

The velocity profile for C_{10} individual hydrocarbon degradation was established by considering change in concentration per time interval that is V_1^{10}, V_2^{10}, V_3^{10} V_4^{10} and V_5^{10} from Figure 6. Decrease in C_{10} individual hydrocarbon degradation was observed with increase in time. Attributing the order of magnitude of the individual hydrocarbon degradation and diffusion in the various soil samples revealed that the SS > CS > LS and the characteristics of the behavior of the C_{10} individual hydrocarbon degradation in this case can be attributed to the physicochemical properties of the soil as well as the environmental factors.

4. CONCLUSION

In conclusion, it was observed that the decrease in n- decane (C_{10}) individual hydrocarbon degradation was observed with increase in time. The decrease may be attributed to the order of magnitude of the individual hydrocarbon degradation and diffusion in the various soil samples revealed that the decrease in sandy soil is greater than that of clay soil and loamy soil, while that of clay soil is greater than that of loamy soil, which can be presented in simpler form as (SS > CS > LS) and the characteristics of the behavior of the C_{10} individual hydrocarbon degradation in this case can be attributed to the physicochemical properties of the soil as well as the environmental factors.

Informed consent

Not applicable.

Ethical approval

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Funding

The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

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